

ESTIMATING THE IMPACTS OF ACCESS MANAGEMENT WITH MICRO-SIMULATION: LESSONS LEARNED

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by

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ABSTRACT

This paper describes research sponsored by the Texas Department of Transportation (TxDOT) to investigate the operational impacts of access management techniques—raised medians and driveway consolidation. Operational impacts (travel time, speed, and delay) were investigated through micro-simulation on three field test corridors and three theoretical corridors. Proof-of-concept and preliminary results of the time-to-collision (TTC) measure for safety analysis are also described in this paper.

The proposed future conditions (approximately a 20 percent increase in traffic) with a raised median resulted in a percent increase in travel time from two to 57 percent on two test corridors, and a decrease of 11 to 38 percent on one test corridor compared to the two-way left-turn lane (TWLTL). The travel time increases equated to as much as a six mile per hour decrease in speed on one corridor and an increase of 7 mph on another corridor. A similar percent increase with the raised median compared to the TWLTL was found with the theoretical corridors—equating to an average speed decrease of three miles per hour. The travel time differences are based upon the traffic level and location/number of the raised median openings. This relatively small change in travel time and speed would appear to be outweighed by the reduction in the number of conflict points and increased safety experienced with raised median installation. Detailed crash analysis was also performed as part of this TxDOT research effort; however, the focus of this paper is on the micro-simulation of operational impacts.

Finally, future research needs are identified in the paper including the need to investigate operational and safety impacts over a broader range of geometric conditions and longer corridors than investigated here. It should be noted that the results of this analysis are from a limited number of test corridors and simulation runs. The results should not be taken as representative for other areas as detailed micro-simulation is often necessary at each site-specific location. The information provided in this paper is anticipated to be useful for transportation professionals seeking additional information on the potential impacts of raised medians and driveway consolidation, two common access management techniques, as well as information on using micro-simulation for analyzing access management treatments.

INTRODUCTION

The primary purpose of arterial streets is to move vehicles while providing necessary access to residential and commercial developments. Unlimited access directly from businesses and/or residences to arterial streets causes average speeds to decrease and diminishes the capacity of the arterial. Frequent access also presents safety concerns by providing more locations for potential conflicts of vehicles' paths. Incorporating access management techniques such as raised medians and low driveway density into the design of arterials can have a positive impact to the safety and operation of the roadway. This practice is most successful when included in the original design of the arterial, but can also be applied through retrofit projects on existing roads.

In recent years, there has been increased interest in access management principles and techniques in Texas. The Texas Transportation Institute (TTI) assisted the Texas Department of Transportation (TxDOT) Design Division in the development of the TxDOT *Access Management Manual (1)*. This paper highlights the findings of a recent research effort sponsored by TxDOT and performed by TTI to estimate the safety and operational impacts of access management in Texas. This paper will focus on the operational impacts observed by using the Verkehr in Städten Simulation (Traffic in Cities-Simulation) (VISSIM) micro-simulation at three selected field sites in Texas and three theoretical corridors created to investigate the impacts on operations (travel time, speed, and delay) with different driveway spacings, median treatments, and traffic volumes.

Since completing this work for TxDOT, the research team has also been investigating the including the time-to-collision (TTC) surrogate safety measure into VISSIM through funding from the Southwest Region University Transportation Center (SWUTC). Preliminary results of the TTC are also described and presented in this paper. Finally, for the interested reader, the safety analyses performed for TxDOT can be found elsewhere (2-4).

METHODOLOGY FOR ANALYSES

The research team identified three case study locations for micro-simulation analysis in Texas. The geometric characteristics of these test corridors are shown in Table 1. Traffic performance (travel time, speed, and delay) was simulated before and after raised medians were implemented. In the "before" period, each corridor was a two-way left-turn lane (TWLTL). Note that the conflict points, travel time, and speed differences shown in Table 1 will be discussed in a later section of this paper.

The VISSIM Micro-simulation Tool

VISSIM is a microscopic, time step, and behavior-based model developed to simulate urban traffic and transit operations (5). The research team chose this micro-simulation tool for its unique ability to simulate multiple-conflict points and dynamics associated with a TWLTL arterial environment. The research team used the model to quantify the performance measures of travel time, speed, and delay along the study corridors.

VISSIM is an ideal tool for modeling changes from a TWLTL to a raised median because of its dynamic routing system. When a route is removed (i.e., a left-turn movement is eliminated when a raised median is installed), VISSIM causes the vehicle to automatically find the next shortest route, which is the next raised median opening. VISSIM can also animate the simulation. Therefore, the user can visually identify any problems occurring in the model and check the model for visual accuracy. This visual animation is also an informative tool that the public can easily see and understand.

Although VISSIM is a good modeling tool, it cannot optimize signal timing. Whenever traffic volumes or roadway geometrics change, the user must optimize the signal timing, allowing maximum flow of vehicles through the signalized intersection. Signal optimization was performed in SYNCHRO for this analysis and incorporated into VISSIM. Comparing the incremental benefits of various alternatives is more accurate when all the scenarios have optimized signal timing. Three micro-simulation runs were performed for each case study and each theoretical corridor and the results were averaged for a given ADT and corridor.

Table 1. Characteristics and Results of Case Study Corridors

Case Study	Location	Corridor Length (miles)	Signals per Mile / Access Points per Mile ¹	Median Opening Spacing (feet) ²	Number of Lanes Each Direction ³	Land Uses	Percent Difference in Conflict Points ⁴	Estimated Existing ADT ⁵	Estimated Future ADT ⁶	Future Percent Difference in Travel Time ⁴	Future Actual Difference in Speed (mph)
Texas Avenue	Bryan, Texas	0.66	3.0 / 91	690 to 1,320	2	Retail, University	-60	18,200	21,800	-11	2 (increase)
									48,000	-38	7 (increase)
31 st Street	Temple, Texas	0.71	5.6 / 66	350 to 850	2	Retail, Some Residential	-56	13,300	16,000	3	1 (decrease)
Broadway Avenue	Tyler, Texas	1.47	4.1 / 46	500 to 1,500	3	Commercial, Retail	-60	24,400	29,300	2	<1 (decrease)
									48,000	57	6 (decrease)

¹Access point density includes both directions and includes driveways, streets, and signalized intersections.

²Median opening spacing is the range for the raised median alternative with the most openings. Five alternatives were investigated along 31st Street and two alternatives along Broadway.

³The Texas Avenue and 31st Street corridors were not widened in the micro-simulation because VISSIM allows vehicles to perform U-turns with two lanes, and this study was intended to investigate the differences between the TWLTL and the raised median. From a practical perspective, flared intersections and slightly widened mid-block location(s) would facilitate the U-turns.

⁴The percent difference values are from the conversion from a TWLTL to a raised median. Negative values imply a decrease when converting to the raised median. These differences are based upon the weighted average of three micro-simulation runs.

⁵Estimated from road tubes or videotapes. The ADTs are estimated by assuming a K and D factor to apply to the observed peak hour volume.

⁶The lower ADT value is a 20 percent increase over existing conditions. This represents an approximately two percent increase over ten years. The higher ADT value was run to estimate higher-volume conditions. The ADTs are estimated by assuming a K and D factor to apply to the observed peak hour volume.

Inputs and Coding in VISSIM

The first step in creating the micro-simulation model was gathering the necessary data. Generally, the research team obtained an aerial photograph of the case study for use as the background in VISSIM. Researchers manually collected the necessary geometrics such as lane configurations, lane widths, driveway widths, distance between driveways, and lengths of dedicated lanes. They also collected traffic volumes on the mainlanes and turning movement counts at signalized intersections and driveways along the corridor. These counts were typically taken during the noon and evening peak periods. Researchers also obtained signal timing for the signalized intersections on the corridor. Finally, the team completed travel time runs using the floating-car method (6) in both directions on the corridor during the peak hour. The data collected during the travel time runs were used in the calibration process to ensure that the VISSIM model was operating in a similar manner to the floating-car travel time data collected in the field.

Research team members input the gathered information into VISSIM, which was a tedious task. For a new user, entering these data can be a very time-consuming process. However, as the user becomes more familiar with the software, this stage of the modeling procedure becomes easier and less time consuming. For a more detailed description of the input and coding processes, refer to the VISSIM procedure described in detail elsewhere (2,3).

Testing and Calibrating VISSIM

Once the VISSIM model was completed, it was tested and calibrated. Researchers reviewed the on-screen animation and model outputs to determine the model's accuracy in simulating field operations. The user then viewed the on-screen animation to check the realism of queue lengths. The researchers then compared the travel time outputs to those collected with the field travel time runs. Speed distributions were altered slightly (when necessary) to ensure that the VISSIM model's travel times were similar to the floating-car travel time data collected in the field.

Theoretical Corridors

Table 2 provides the geometric characteristics of the theoretical corridors. The percent differences in the conflict points and travel time columns shown in Table 2 are discussed in the next section of this paper. The theoretical corridors were investigated to cover a broader range of traffic volume ranges and geometric characteristics (raised medians and driveway consolidation) than evaluated with the field test corridors. The design of the theoretical corridors began with identifying typical land uses for the 1.0-mile corridor with one set of signals separated by 0.5 mile. The goal of the researchers was to design a realistic representation of a typical corridor. Some of the land uses included a drive-in bank, pharmacy/drugstore, fast-food with drive-through, and gas station. In Scenario 1, 18 driveways represented 18 parcels with varying land use types; some were used more than once. In Scenario 2, 42 driveways represented 42 parcels with repeating land uses. While Scenario 3 contained the same number of parcels as Scenario 2, with the same land uses, each parcel in Scenario 3 had two driveways, making a total of 84 driveways. In all scenarios there are an equal number of driveways on the north and south sides along the corridor, and the driveways lined up across the road (see Table 2 for Scenario characteristics). Once the land uses were identified, the researchers used the Institute of Transportation Engineers (ITE) *Trip Generation* manual to estimate the number of trips generated and the directional distribution (entering/exiting) of each particular land use (7). In Scenario 3, the trips generated were divided equally between the two driveways. The vehicles exiting all driveways in all scenarios were divided equally—50 percent left-turning and 50 percent right-turning. This was also true for all vehicles entering the driveways—50 percent enter from one direction and the other 50 percent enter from the other direction.

Scenarios 1 and 2 evaluated average daily traffic (ADT) volumes at 18,000, 23,000, 28,000 and 48,000. The research team added ADTs of 33,000 and 38,000 to Scenario 3's evaluation. For a given ADT level and simulation run, the same number of vehicles entered the corridor from each end. The actual number of entering vehicles was calculated by estimating the directional design hour volume (DDHV), which was accomplished by multiplying the ADT by the K factor (0.135) and the D factor (0.5). The K factor was estimated for a suburban area (10), and the D factor assumed an equal split of traffic from each direction. For the raised median conditions, VISSIM automatically rerouted the existing traffic to their final destination using the shortest route. For example, a left-

turning motorist that was prohibited by the installation of the raised median would turn right and then make a U-turn at the first median opening.

Table 2. Theoretical Corridor Characteristics and Results

Theoretical Corridor	Median Treatment ¹	Number of Lanes in Each Direction	Percent Difference in Conflict Points ²	Number of Driveways	Driveway Spacing (feet)	Raised Median Opening Spacing (feet)	Estimated Future ADT ³	Future Percent Difference in Travel Time ²	Future Actual Difference in Speed (mph)
Scenario 1	TWLTL and Raised	2	Not Applicable	18	660	660	18,000 to 28,000	Not Applicable	Not Applicable
Scenario 2	TWLTL	2	-70	42	330	660	18,000	2	<1 (decrease)
							23,000	6	2 (decrease)
	Raised						28,000	31	8 (decrease)
	TWLTL	3	-70	42	330	660	18,000	8	2 (decrease)
							23,000	8	2 (decrease)
							28,000	11	3 (decrease)
	Raised						48,000	44	9 (decrease)
Scenario 3	TWLTL	3	-75	84	165	660	18,000	6	2 (decrease)
							23,000	1	<1 (decrease)
							28,000	2	<1 (decrease)
							33,000	7	2 (decrease)
							38,000	22	6 (decrease)
	Raised						48,000	10	3 (decrease)

¹ Scenario 1 can be considered as both a TWLTL and a raised median because, due to the driveway spacing, there is no change in the conflict points and turning locations.

² The percent difference values are from the conversion from a TWLTL to a raised median. Negative values imply a decrease when converting to the raised median. These differences are based upon the weighted average of three micro-simulation runs.

³ The ADTs are estimated by assuming a K and D factor to apply to the observed peak-hour volume.

FINDINGS OF THE TEST CORRIDORS AND THEORETICAL CORRIDORS

Qualitative Findings of Test Corridors

While the VISSIM model appears to be a very promising micro-simulation tool for simulating access management treatments, there is a steep learning curve for analysts. Throughout the research project, the research team continued to learn more about the VISSIM model and received frequent software updates for VISSIM from the developers.

One specific consideration with micro-simulation is that the results should be based on numerous runs of the same conditions along a corridor. This is because VISSIM is a stochastic model in which the numerous input variables are modeled—often according to distributions (e.g., speed, acceleration characteristics, vehicle types, and motorist behavior). Therefore, each run of the simulation provides one estimate of the performance measure. The results of this research generally required three runs to get results that appeared to converge on an acceptable average value for the performance measures.

VISSIM has outstanding output abilities that allow the user to analyze many aspects of the corridor. For this study, the researchers analyzed travel time, speed, and delay. Travel time and speed results are the focus in the discussion here; however, the results for delay can be found in the full report (3). The results for delay are similar to those

described in this paper for travel time. VISSIM allows the user to choose the duration for the analysis. Researchers selected an hour as the peak time for analysis. This time limit also facilitated the analysis by narrowing the results to those that will be most useful for design hour analysis.

Micro-simulation tools allow for detailed analysis of traffic systems and have great potential for analyzing access management strategies. They implicitly account for the stochastic nature of the transportation system and can provide both temporal and spatial information down to the individual vehicle level. The research team has prepared a conference paper that documents some of the lessons learned while assessing the impacts of access management using micro-simulation (8). The conference paper describes the desirable input and output characteristics of a micro-simulation tool for possible use in investigating access management alternatives. One input characteristic is that the micro-simulation tool includes the opportunity to input the complex conditions that must be considered when evaluating access management improvements. The ability for the micro-simulation model to manage geometric inputs is clearly important when evaluating access management techniques because access management strategies often include changes in roadway geometry. It is imperative that the model allow for locating driveways in their environment to scale. There must also be the ability to include acceleration or deceleration lanes (common access management techniques) in combination with these driveways. Turning radii and lane width are also important geometric factors that are necessary in the roadway network.

The micro-simulation tool must also have the ability to handle numerous operational inputs that affect traffic flow. These include gap acceptance, speed, and acceleration characteristics. Accurate traffic signal simulation is also an important element for a micro-simulation tool because signal spacing is an important access management treatment. In addition, accurate traffic signal operations and traffic progression are required if micro-simulation tools are to be used successfully. Because the success of traffic signal treatments depend on proper timings, it is important that the simulation package, 1) have traffic signal optimization routines, or 2) allow for the importation of traffic signal data to be input from external traffic signal software.

It is important that traffic operation effects (i.e., reduction in delay and/or travel time) can be solely attributed to the transportation improvements made to a given corridor, and not due to changes in traffic operations along the corridor (i.e., weaving). Therefore, it is imperative that users have complete control of the network demand. This can be accomplished by providing a method to input origin-destination pairs and paths or exclusively handle routing decisions of vehicles so that changes between simulation runs and alternatives do not include the influences of weaving maneuvers.

Finally, the analyst must understand the underlying theory behind the micro-simulation model, and the model must also be calibrated to field conditions. The underlying theory will affect driver behavior, vehicle type characteristics, and traffic flow within the context of the other input parameters. Generally, there are input parameters within the model that can be adjusted to better reflect field conditions.

Considering the output characteristics necessary for a micro-simulation tool used for evaluating access management techniques is also important. For access management applications, the analysis requires the ability to analyze the system at any level of spatial or temporal detail. In particular, this is required at the individual level to provide for both disaggregate and aggregate analyses. Output is necessary for different locations (spatially) along the corridor where access management treatments are being evaluated. For example, signalized and unsignalized intersection and/or raised median openings may be locations where traffic operations are of particular interest. Temporal output that allows investigation of traffic operations through time is also necessary as it allows the analyst to investigate platooning, queuing, and other time-based operations. Micro-simulation allows for this investigation at the individual vehicle level.

It is also beneficial if the micro-simulation software provides an animation feature to allow the analyst to watch the simulation run to provide a visual check of consistency and to ensure there are no suspicious movements in the network (e.g., vehicles colliding). Further, animation abilities are valuable for graphically illustrating the operation and impacts of corridors after access management techniques have been implemented.

Quantitative Findings of Test Corridors

Each micro-simulation corridor was investigated with numerous alternatives. Each corridor began with a TWLTL as the existing condition. Therefore, the first step was to optimize the traffic signals. This always resulted in at least some improvement in travel times—indicating the tremendous benefit of this relatively simple operational change. For the interested reader, the benefits of signal optimization are further described in a recent Institute of Transportation Engineers (ITE) Journal article (9). The next alternative or alternatives included the proposed condition of a raised median along the corridor with existing traffic volumes. There were then raised median alternatives to better serve specific origin-destination patterns of each specific corridor driveways and streets. The final alternatives always included the future conditions with the TWLTL and with the raised median alternatives that were investigated for the particular corridor. The results shown in Tables 1 and 2 compare the TWLTL with the raised median alternative with the most median openings—the most likely alternative to be implemented. The additional alternatives analysis can be found elsewhere (3). When the average daily traffic (ADT) was not readily available from 24-hour loop counts, it was estimated by dividing the directional design hour volume (DDHV) by an assumed K factor of 0.135 for suburban areas (10) and a D factor of 50 percent. The DDHV was the volume “entering” each end of the corridor for the VISSIM micro-simulation during the peak (design) hour.

Table 1 shows the percent reduction in vehicular conflict points when going from a TWLTL to a raised median treatment for the three case study locations. The percent reduction varies from 56 to 60 percent. Research performed through the National Cooperative Highway Research Program (NCHRP) has shown that reduced conflict (access) points are related to a reduction in crashes along arterials (11).

While the three corridors show nearly the same percent reduction in conflict points, the percent difference in travel time varies for each corridor. This difference is between a TWLTL and the raised median in the future traffic volume conditions. Existing condition traffic volumes were increased 20 percent to obtain the future traffic volumes. This equates to approximately two percent per year for ten years. A negative travel time value in Table 1 indicates that the raised median had a shorter travel time for vehicles traversing the corridor. On the Texas Avenue corridor (ADT ~21,800), travel time decreased 11 percent with the raised median compared to the TWLTL. For Texas Avenue at an ADT of approximately 48,000, travel time decreased 38 percent with the raised median installation. The speed increased by 2 mph at the ADT of approximately 21,800, and it increased by 7 mph at an ADT of approximately 48,000. Figure 1 graphically displays that as volume increases, speed decreases for both the raised median and TWLTL alternatives along Texas Avenue.

The travel time along 31st Street in Temple increased three percent (approximately 1 mph decrease at the only ADT level of 16,000 that was investigated). Along Broadway Avenue in Tyler, the travel times increased two percent (<1 mph decrease) when the raised median was installed at the lower ADT level (29,300). At the higher ADT level of 48,000, there was a 57 percent increase in travel times with the raised median. This equates to a 6 mph decrease in speed. Figure 2 illustrates the decreased speed with the implementation of the raised median at various ADT levels. It should be noted that generally the more circuitous travel and increased U-turn traffic can cause the raised median treatment to have slightly longer travel times. However, it is hypothesized that these increases in travel time, and subsequent delay, are offset by the reduction in the number of conflict points and increased safety. Though not performed, it is also hypothesized that further analysis could have found that an additional median opening(s) could reduce the percent differences between the TWLTL and raised median even further.

Quantitative Findings of Theoretical Corridors

While the actual case study locations presented here are valuable in assessing the impacts of access management treatments, additional theoretical scenarios were also analyzed. These additional scenarios were developed for TxDOT staff members for alternatives analysis. Researchers met with TxDOT in the first year of this project to identify the most useful scenarios for their typical needs. Three theoretical corridors incorporating access management treatments such as raised median installation and driveway consolidation were investigated for different traffic volumes as a result of that meeting. The design of the theoretical corridors and the travel demand used for the analyses were described previously. Analysis of the theoretical corridors addressed the number of conflict points, travel time, speed, and delay. These results help researchers begin to identify operational characteristics resulting from changing to raised medians from TWLTLs and altering driveway density.

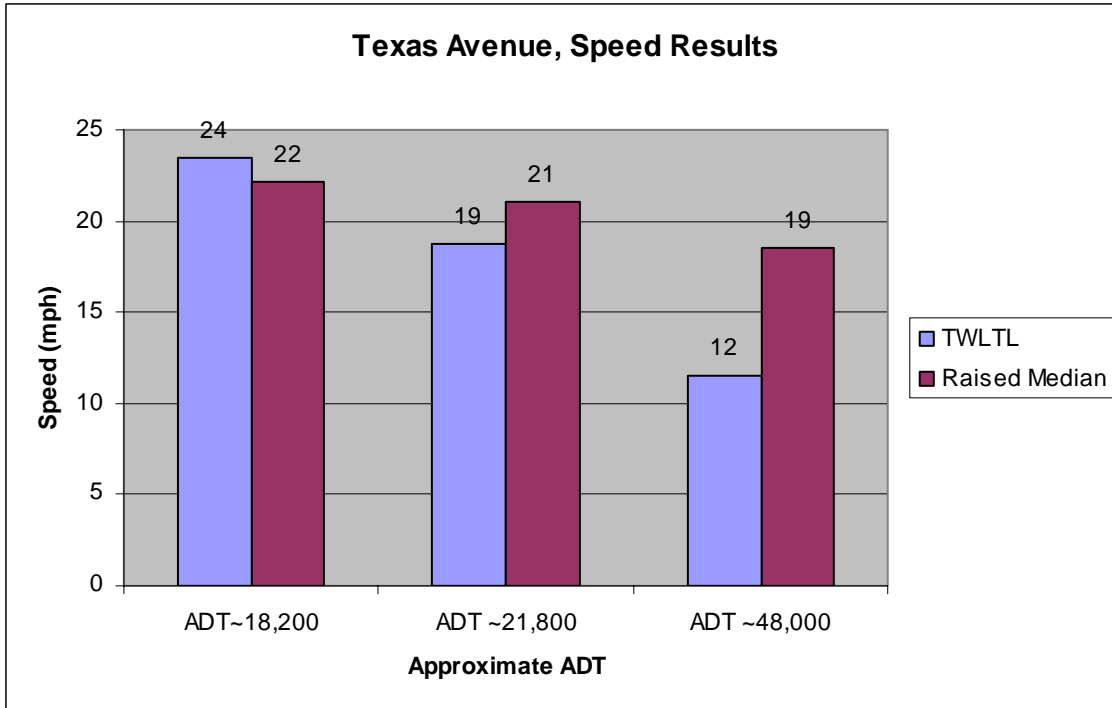


Figure 1. Texas Avenue Speed Results

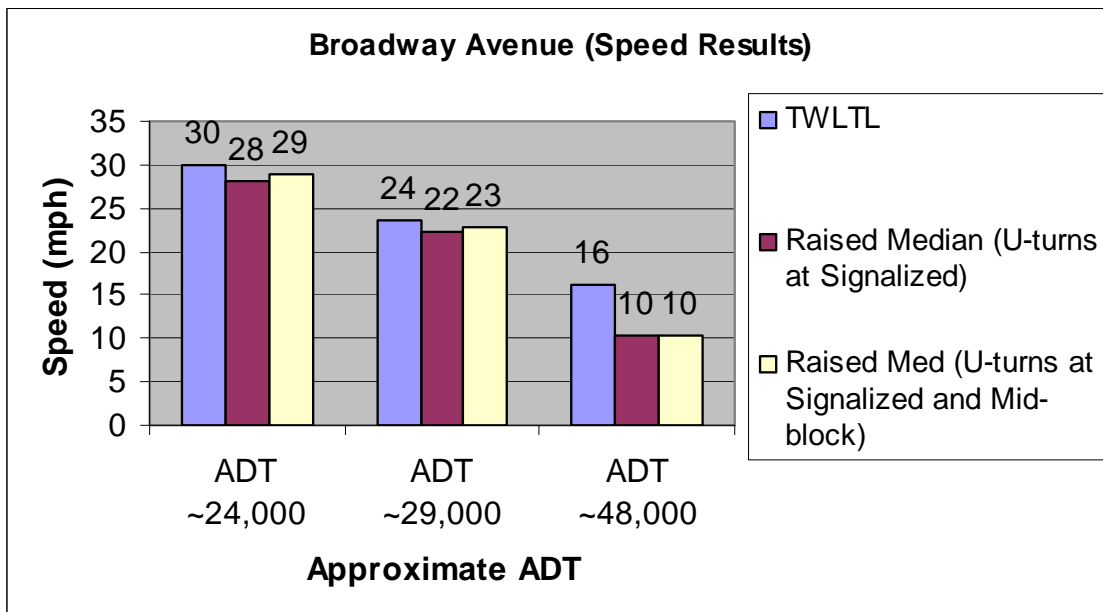


Figure 2. Broadway Avenue Speed Results

Safety is an important aspect of access management. A reduction in the number of conflict points within a corridor will likely reduce the number of crashes within that corridor. Installing a raised median is an excellent way to reduce the number of conflict points. This is demonstrated in Scenario 3. When a raised median is added to the corridor, the number of conflict points decreases from 1220 to 300, a decline of approximately 75 percent. Scenario 2 also showed a large decrease in the number of conflict points after the addition of a raised median. Another way to reduce the number of conflict points is to reduce the number of driveways along the corridor. When the number

of driveways increased from 18 to 42, the total conflict points for the scenarios with a TWLTL increased from 338 to 650 (five-lanes) and 674 (seven-lanes), an increase of approximately 50 percent.

Table 2 illustrated all the theoretical scenarios and their results. As in the case studies, the number of conflict points decreases with the installation of a raised median. This decrease occurs even when the number of driveways increases from 18 in Scenario 1 to 84 in Scenario 2, an increase of approximately 460 percent. The number of conflict points for both the five- and seven-lane options for Scenario 2 was reduced by 70 percent with the installation of a raised median. This large reduction is accompanied by an increase in travel times with the raised median by from 2 to 31 percent for the five-lane option and from 8 to 44 percent for the seven-lane option. The Scenario 3 results show a 75 percent reduction in the number of conflict points with the installation of a raised median, along with a 1 to 22 percent increase in travel time.

These results generally demonstrate an increase in travel time along the corridor for through-moving vehicles due to the circuitous travel of U-turning traffic and the associated weaving of these maneuvers. The actual reduction in speed is, on average, approximately three miles per hour when a raised median replaces a TWLTL. It is hypothesized that these relatively small differences would likely be justified with the associated reduction in conflict points and potential safety increase along such corridors. These analyses also make assumptions about traffic patterns entering and exiting the corridors. Along and around an actual corridor, observation rather than simulation would allow a better understanding of the origin-destination patterns which might lead to better management of traffic circulation.

Future research in this area should continue investigating the relationship between median type, driveway density, and traffic volume. In the theoretical corridors, the median opening spacings were set at 1/8-mile (660 feet), and it would be interesting to investigate the potential changes in travel time with different median opening spacings. It would also be interesting to investigate these parameters over longer corridors to gain insight into potential changes over longer distances. It is preferable that such analyses be conducted on actual field sites, along with an associated crash analysis, though finding such a site and performing such data collection could be difficult and costly.

TIME-TO-COLLISION AS SURROGATE SAFETY MEASURE IN MICRO-SIMULATION

To date, analysts have had to review crash reports (if available) for corridors to investigate the safety of installed treatments while operational improvements (travel time, speed, and delay) could be investigated through micro-simulation. Recent research sponsored by the Federal Highway Administration (FHWA) has investigated the inclusion of surrogate safety measures into micro-simulation (12). Ultimately, such methods would allow the analyst to obtain estimates of safety impacts from transportation alternatives in the same micro-simulation model that provides operational performance data. The FHWA work describes surrogate safety measures such as the time-to-collision (TTC) concept. A TTC value at any instant is defined as the time that remains until a collision between two vehicles would occur if the collision course and relative speed difference are maintained, and it can be calculated as the distance between the vehicles divided by the speed difference between the vehicles. The TTC is only meaningful if a positive speed difference exists between the vehicles. It is generally assumed that higher TTC values indicate safer situations, and that safety-critical situations are characterized by small TTC-values. By choosing an appropriate threshold TTC value, it is possible to distinguish between relatively safe and safety-critical encounters. A percentage of the TTCs under a certain time in seconds for the micro-simulation can be used as a surrogate for safety. The intent is that the TTC would identify the stop-and-go acceleration characteristics that might be present for different transportation alternatives—allowing them to be compared from a safety perspective. TTI is in the process of investigating the use of the TTC in the VISSIM environment with the micro-simulation test corridors described in this paper. Proof-of-concept was initially illustrated by TTI in a previous conference paper (8). Preliminary results of applying the TTC to the case studies and theoretical corridors are presented in this paper. The results described above in the travel time and speed comparisons were based upon three micro-simulation runs. The results here are based upon only one simulation run as the research team continues to perform analysis on the TTC.

TTI researchers developed a computer program using the Borland Delphi software that would post-process the *.fzp output file from VISSIM for TTC computations. The *.fzp file is the VISSIM vehicle record file, and it includes vehicle location and speed information at whatever time step is used by the analyst. When using micro-simulation to determine TTC values, it should be taken into account that simulated drivers are “perfect” in that they do not

suffer from inattentiveness, misjudgments, and errors that result in many crashes in real life. Consequently, the assumption can be made that a slightly higher threshold TTC value has to be used in micro-simulation in order to account for the “perfect” drivers in the simulation. For this reason, a threshold TTC value of 4.0 seconds was chosen for this graphic example.

Figure 3 shows a snapshot from the screen as the program was running in VISSIM. The graph shows that approximately 0.79% of the travel time on the network is spent at TTC values less than 4.0 seconds. By comparing the percentage of time spent below TTC threshold as well as the general shape of the TTC distribution between different access management alternatives, it may be possible to compare their relative safety performances. This was not done in this example, since the current version of the software only calculates TTC values between following vehicles, and thus excluded TTC values between vehicles conflicting at angles. A future version of the software will include TTC values between conflicting vehicles at angles. However, the process appears to be promising, and it was applied to the case studies and theoretical corridors.

Figure 4 shows the harmonic mean of the TTC for the Texas Avenue (Bryan, Texas) case study, and Figure 5 shows the harmonic mean of the TTC for the Broadway Avenue (Tyler, Texas) case study. Note that the harmonic mean is used to ensure that very large TTC values become negligible. There are numerous large TTC values for a given micro-simulation. Figure 4 shows that the TTC harmonic mean for Texas Avenue with the TWLTL is slightly higher than the raised median at the highest ADT level, but not at the lower ADT levels. Figure 5 shows the TWLTL is slightly lower than the raised median along Broadway Avenue at the highest ADT level, which is intuitive. Figure 6 shows that the TWLTL has a slightly higher percentage of TTC values ≤ 10 seconds when comparing the TWLTL with the raised median alternative along Texas Avenue for an ADT of 48,000. Figure 7 illustrates that the TWLTL has the highest percentage of the proportion of vehicle time with the TTC values ≤ 10 seconds at the highest ADT level along Broadway Avenue.

Figure 8 shows the harmonic mean of Scenario 2 and Scenario 3 by ADT level. It is interesting to note that the Scenario 2 (TWLTL) had the lowest TTC for each ADT level (as one might expect). Similarly, Figure 9 shows that the proportion of time with TTC ≤ 10 seconds for Scenario 2 (TWLTL) was always the highest. This is intuitive because one would expect the larger percentage of TTC at a relatively low value with a TWLTL alternative where there might be more stop-and-go traffic and more weaving operations.

In general, the numerical analysis here provides proof-of-concept for the TTC application in VISSIM. There are numerous variables that have not been controlled in this analysis. One item of particular note is that the simulation runs for this analysis have only been performed one time, and it is possible that there is simply variability in the results of simulation runs that are not being considered here because the results are not averaged for several runs. This may cause some of the anomalies in the results shown here. After more micro-simulation runs are performed, the research team will investigate statistical differences between the TTC results and the alternatives.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

In recent years, there has been increased interest in access management principles and techniques in Texas. The paper highlighted the findings of a recent research effort sponsored by TxDOT and performed by TTI that estimated the operational impacts of access management in Texas.

Operational Impacts Assessed through Micro-simulation

Although it is a valuable micro-simulation tool, VISSIM is a sophisticated program with a steep learning curve for a new user. Any initial difficulty is primarily due to VISSIM's numerous sophisticated input and output capabilities. The process of inputting the different types of data into the micro-simulation was difficult and time-consuming. Further, each alternative was run several times with visual examination to ensure the corridor was running correctly.

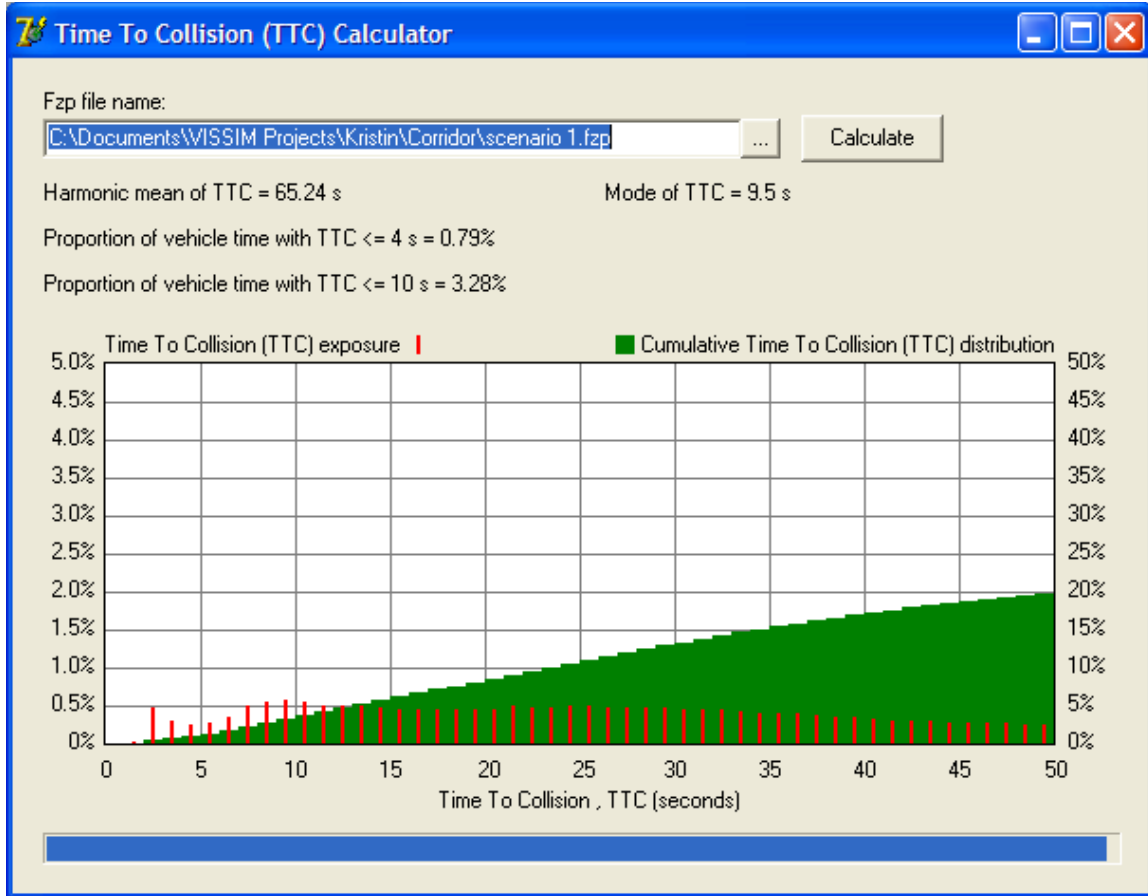


Figure 3. Time-to-collision Calculator Developed for VISSIM (Reference 8)

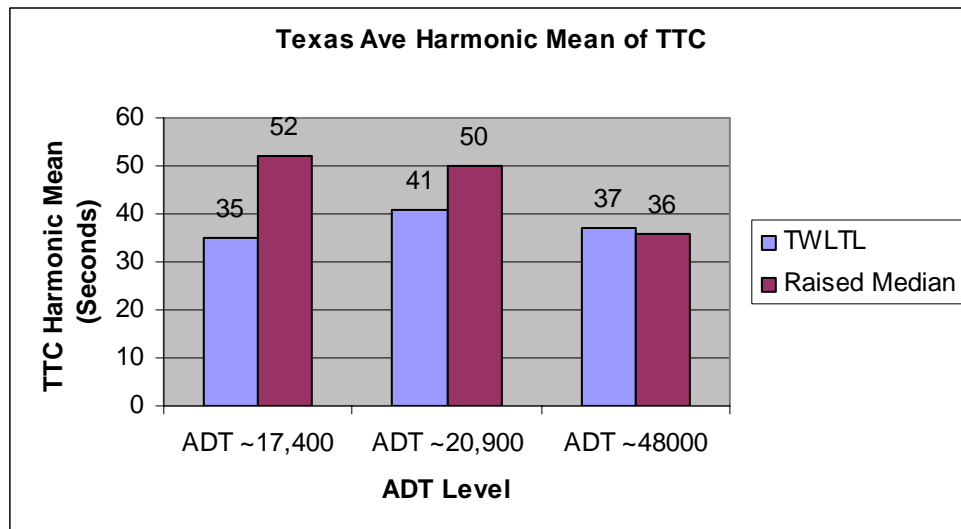


Figure 4. Texas Avenue TTC Harmonic Mean by Median Type

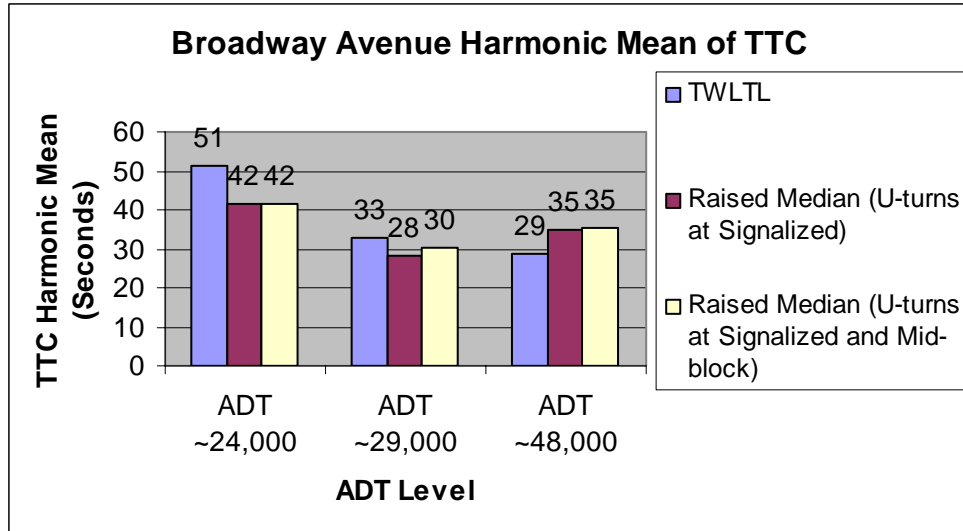


Figure 5. Broadway Avenue TTC Harmonic Mean by Median Type

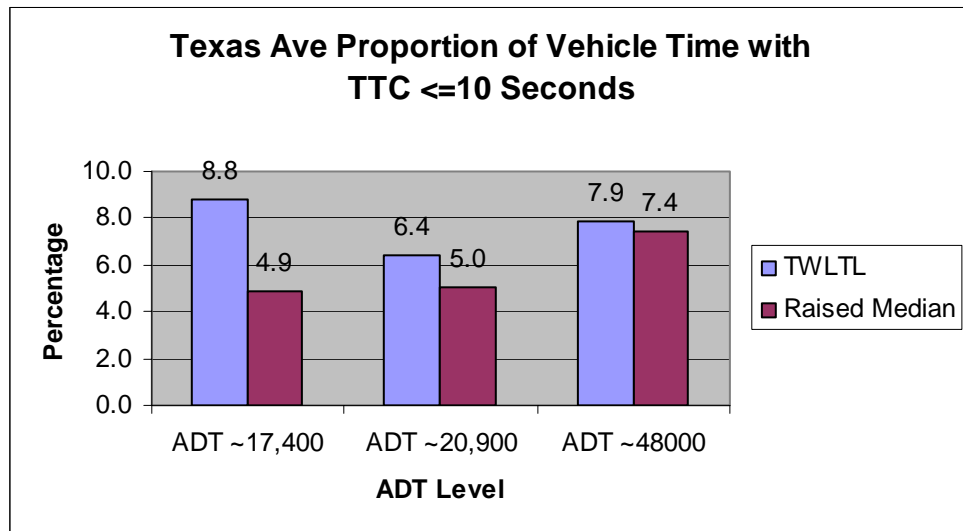


Figure 6. Texas Avenue Proportion of Vehicle Time with $TTC \leq 10$ Seconds by Median Type

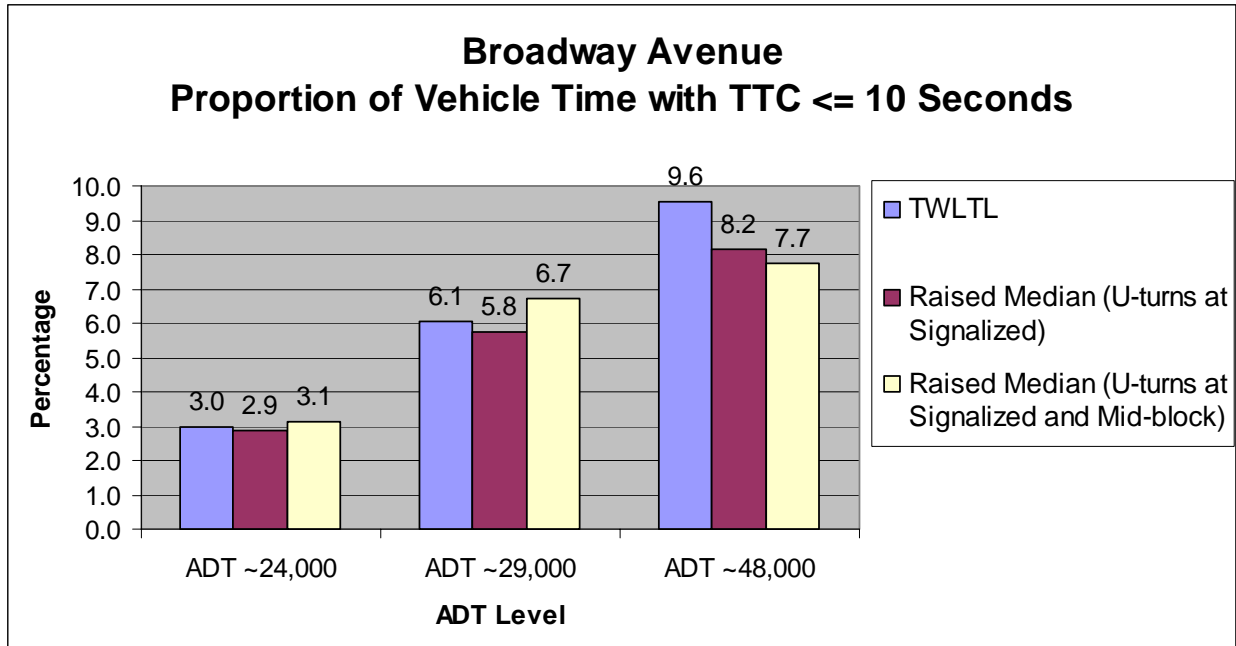


Figure 7. Broadway Avenue Proportion of Vehicle Time with $TTC \leq 10$ Seconds by Median Type

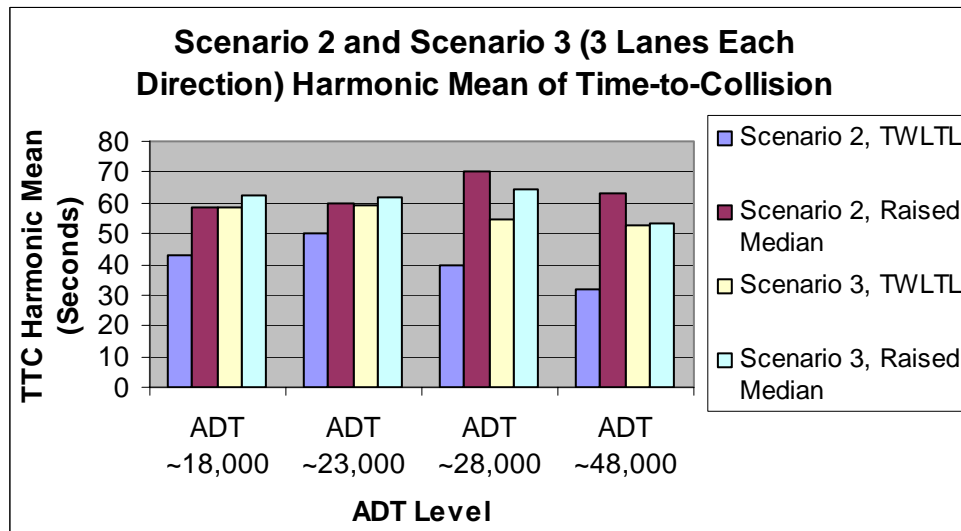


Figure 8. Scenario 2 and Scenario 3 TTC Harmonic Mean by Median Type

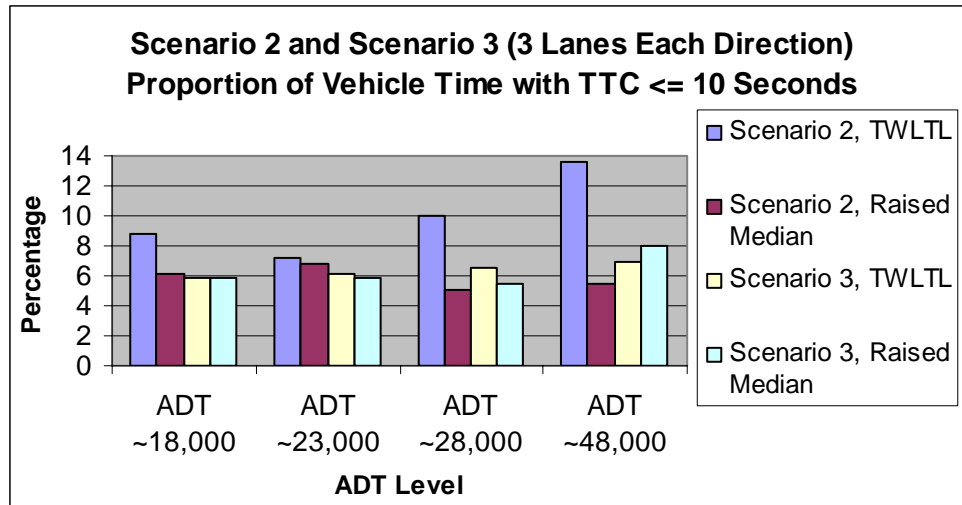


Figure 9. Scenario 2 and Scenario 3 Proportion of Vehicle Time with $TTC \leq 10$ Seconds by Median Type

VISSIM allows the user to change numerous model inputs and to input the necessary available field data, which are both important aspects of the program. Users can adjust design elements such as driveway spacing, number of lanes, speed limits, and right-turn-on-red. VISSIM also allows the user to input signal timing and phases after they are optimized in a separate program such as SYNCHRO, which was used in this project. The optimized timings and phases were entered into VISSIM from SYNCHRO, another time-consuming process in alternatives where multiple scenarios have multiple signals. The most time-consuming portion of the process is entering all the data into VISSIM and ensuring the corridor is calibrated to field conditions.

VISSIM's output abilities are just as impressive as the input characteristics. For this study, travel time, speed, and delay were analyzed in the case studies and the theoretical corridors. For this project, the research team simulated the peak hour. This research found that VISSIM was useful for studying the effects of access management. It should be noted that other software packages may be equally useful—only VISSIM was investigated for this study.

The analysis results for the three case study corridors revealed small differences in travel time and delay between the existing (TWLTL) and proposed (raised median) conditions. The proposed future conditions (approximately a 20 percent increase in traffic) resulted in a small percent increase in the overall travel time and delay. The percentage difference in travel time, speed, and delay varied for each corridor. Travel time on the Texas Avenue (Bryan, Texas) corridor decreased 11 to 38 percent with the raised median compared to the TWLTL in the future condition. Travel time on the 31st Street (Temple, Texas) corridor increased three percent with a raised median compared to a TWLTL in the future condition, and on Broadway Avenue (Tyler, Texas) travel time increased 2 to 57 percent with the raised median treatment compared to a TWLTL in the future. This resulted in a maximum of a six mph decrease in speed due to the raised median installation (Tyler) and as much as a 7 mph increase in speed with the raised median (Bryan). These results are summarized in Table 1. The reduction in travel time on Texas Avenue from the future TWLTL to the future raised median treatment might be attributed to prohibiting U-turns at a high-volume signalized intersection. This forces vehicles to make U-turns at locations farther along the corridor, at uncongested locations. In effect, this takes less time than waiting for turning traffic in the more congested portions of the corridor. This also allows for more through-movement green time, which can be reduced on corridors with high left-turn and U-turn movements. The increased travel times from the future TWLTL to the future installation of raised medians in Temple and Tyler are likely due to overall increases in traffic on the corridor, as some U-turning vehicles must travel farther to reach their destination. Increased travel time is also caused by U-turning vehicles that must weave across lanes to reach turn bays, which can cause traffic queues. The U-turning vehicles are also adding additional traffic on the roadways in the opposite direction of their origin. The additional vehicle-miles of travel (VMT) likely causes travel time and delay to increase. Delay may also increase slightly at the signalized intersections. As note previously, the percent difference in travel time along the Temple corridor was only about three percent when comparing the raised median alternative with the most median openings—the alternative most

effectively handling the corridor turning movements. It is hypothesized that increasing the number of median opening locations could have reduced the percent difference between the TWLTL and raised median alternatives to less than three percent.

The theoretical corridor results also indicate small increases in travel time with the raised median treatment compared to the future TWLTL conditions. The results are presented in Table 2. Scenario 1 did not have a comparison between a TWLTL and a raised median because the driveway spacing was 660 feet, similar to the median openings, so it was essentially the same for both median treatments. Travel time for Scenario 2 (five-lane) increased 2 to 31 percent for the raised median compared to the TWLTL, while that for Scenario 2 (seven-lane) increased 8 to 44 percent with a raised median compared to the TWLTL. The travel time increase with the raised median ranged from 1 to 22 percent in Scenario 3 when compared to the TWLTL. More details on these comparisons can be found in the final report (3). The reasons given for increases in travel time for the case studies are also hypothesized for the theoretical corridors as well. While the percent differences are large in some scenarios, the actual speed reduction average three miles per hour. These small increases in travel time, and subsequent delay, appear to be outweighed by the reduction in the number of conflict points and increased safety—another impact analyzed in this study on additional test corridors.

Future Research Needs

Operational Impacts and Micro-simulation Analyses

More research is needed to further identify the impact of access management treatments over a range of traffic volumes. Although this project identified many valuable findings, primarily related to the potential implementation of raised medians, combinations of access management treatments along a corridor could be further investigated. For example, the presence of acceleration and/or deceleration lanes at heavy driveway or cross-street locations could facilitate traffic movement. Further, along the actual test corridors it is difficult to identify the precise origin-destination patterns of vehicles without a costly origin-destination study to identify vehicle patterns both within and through the study corridor. Although costly, it would also be valuable to investigate longer corridors with combinations of access management techniques, as those provided here were relatively short (0.5 to 1.5 miles).

Implementing an origin-destination (O-D) matrix for vehicle trips is another topic that could be further researched. In the case studies for this project, vehicle origin was used to determine likely destinations through assumptions, which were consistent across scenarios. A matrix was designed in which the vehicle entrance location determined where the vehicle would exit the system; however, due to budgetary limitations, the research team did not automate the O-D matrix. Therefore, ensuring the number of vehicles in the corridor was relatively consistent with field observations required numerous checks.

The theoretical corridors could also use additional research on the effects of travel time, speed, and delay as a consequence of higher traffic volumes. In the theoretical corridors, the spacing of median openings remained constant. The results of varying the distance of the openings would also be of interest. It should be noted that turn bays were on the order of 100 feet in the theoretical scenarios and closer to 250 feet for the case studies. Altering these distances would reduce the queuing into the through lanes. Adding a “dummy” signal to the endpoints of the corridors and theoretical scenarios might also replicate expected field conditions by providing for gaps in the traffic stream that might be observed in the arterial environment. These minor changes could affect the simulation results, and would be useful items to further investigate in future research.

It should be noted that the results of this analysis are from a limited number of test corridors and simulation runs. The results should not be taken as representative for other areas as detailed micro-simulation is often necessary at each site-specific location. Finally, it would be preferable if such further analyses could be performed on actual field sites, along with a crash analysis on the same site, though finding such sites and performing such data collection can be difficult and costly.

Combining Micro-simulation and Safety Analyses

To date, analysts have had to review crash reports (if available and/or reliable) for corridors to investigate the safety of installed treatments and operational improvements (travel time, speed, and delay) could be investigated through

micro-simulation. Recent research sponsored by the Federal Highway Administration (FHWA) has investigated the inclusion of surrogate safety measures into micro-simulation, including the time-to-collision measure (12). Ultimately, such methods would allow the analyst to obtain estimates of safety impacts from transportation alternatives in the same micro-simulation model that provides operational performance data. It should be noted that this method assumes that the simulated drivers select distances and perform lane changes similar to real drivers (i.e., that the underlying theory of VISSIM can reasonably replicate field conditions). Within VISSIM, which provides for reasonably replicating field conditions, these differences would be anticipated to be consistent across simulations. Therefore, at this stage, comparison of TTC values appears to be a promising method for the analysis of the conflict and safety impacts of access management. This concept is being further investigated by the authors for application to access management alternatives analysis. More runs are needed for a given simulation to determine average conditions.

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